

# (12) UK Patent Application (19) GB (11) 2 229 937 (13) A

(43) Date of A publication 10.10.1990

(21) Application No 9006207.6

(22) Date of filing 20.03.1990

(30) Priority data  
(31) 3909932 (32) 25.03.1989 (33) DE

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(51) INT CL<sup>a</sup>  
F01N 3/02

(52) UK CL (Edition K)  
B1T TNRH  
F1B BBB BB120 BB140 BB160 BB200 BB204  
BB206 BB212 BB226 BB228 BB300 BB312  
U1S S1437 S1992 S1994

(56) Documents cited  
None

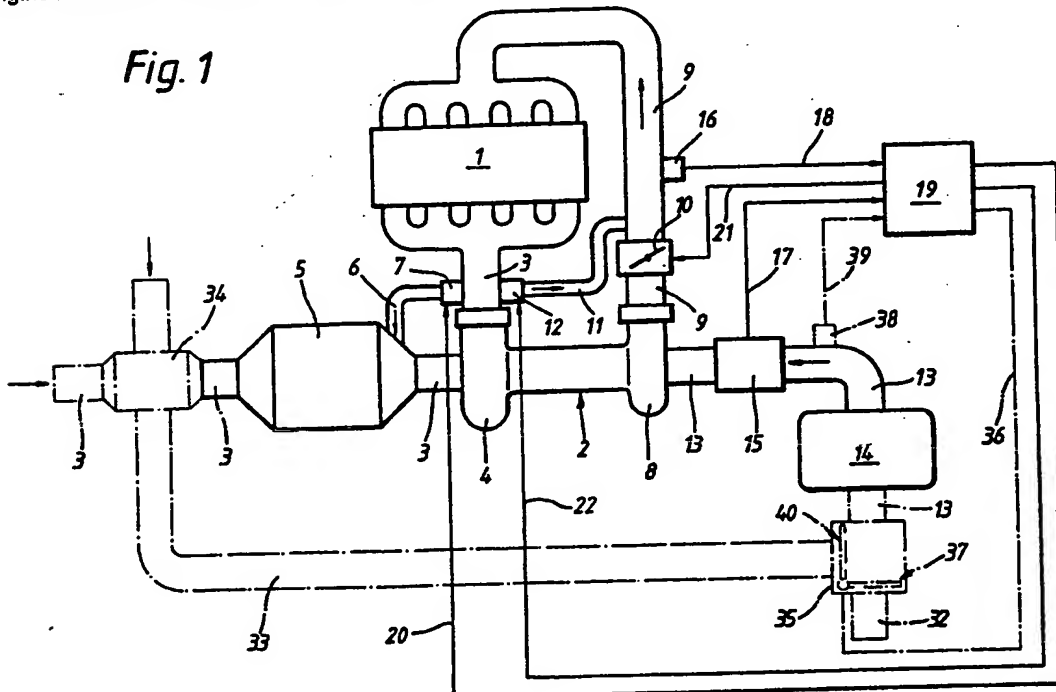
(58) Field of search  
UK CL (Edition J) B1T TNRH  
INT CL<sup>a</sup> B01D, F01N 3/02

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## (54) Regenerating an Exhaust Gas Filter

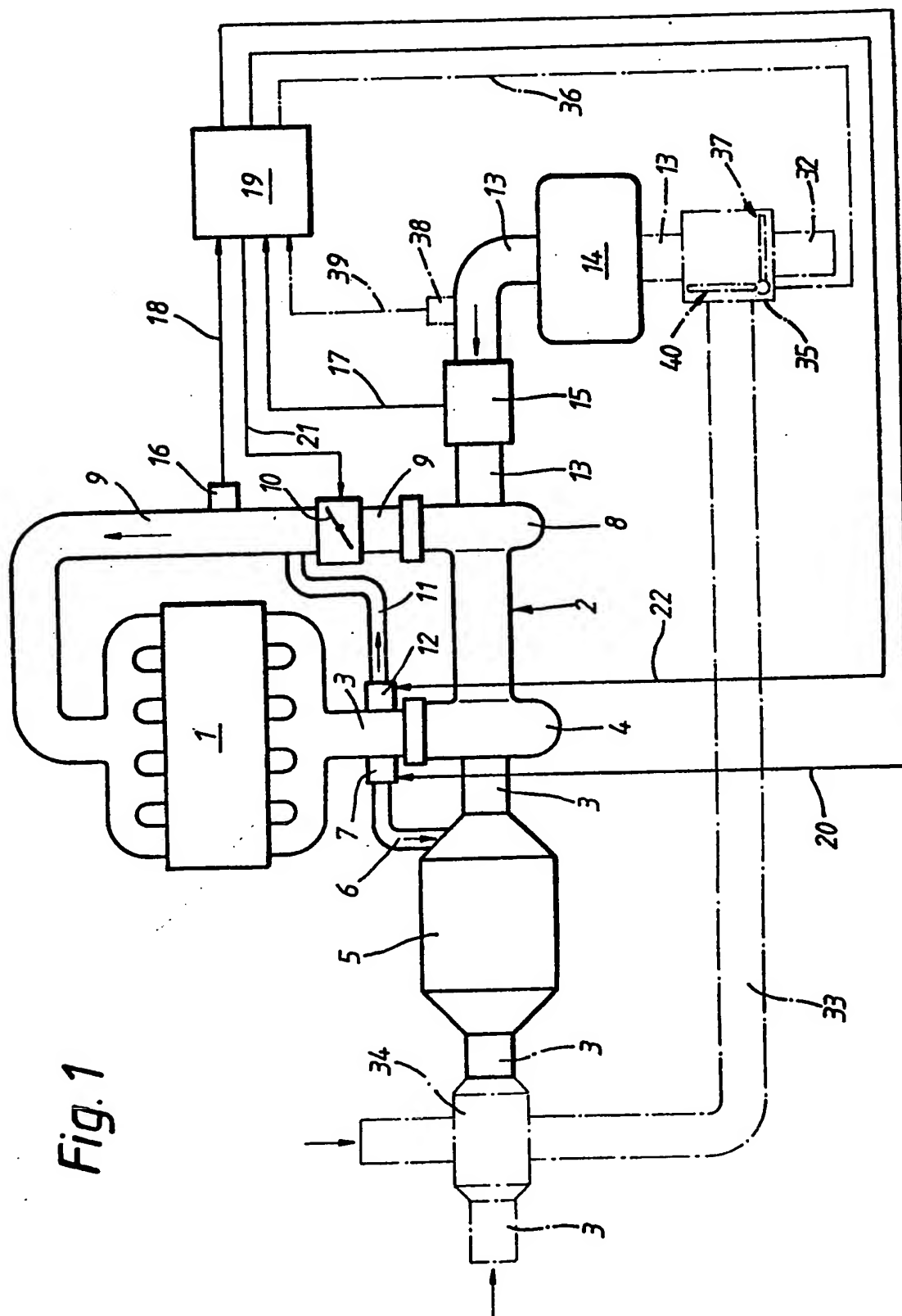
(57) A soot particle filter 5 in the exhaust line 3 of a supercharged diesel engine 1 is regenerated by increasing the exhaust gas temperature. So that an adequate temperature may be achieved at all engine speeds and loads, the speed and load are monitored by unit 19, which controls a valve 7 to bypass all exhaust gas round the supercharger turbine 4 at low loads, thus avoiding cooling of the gas by expansion. At higher loads a variable portion of gas bypasses the turbine. In addition throttle valve 10 and valve 12 in exhaust recirculation line 11 are controlled to raise the temperature at low loads, and for the engine intake air is variably heated by heat exchanger 34 and mixing valve 35.

Fig. 1



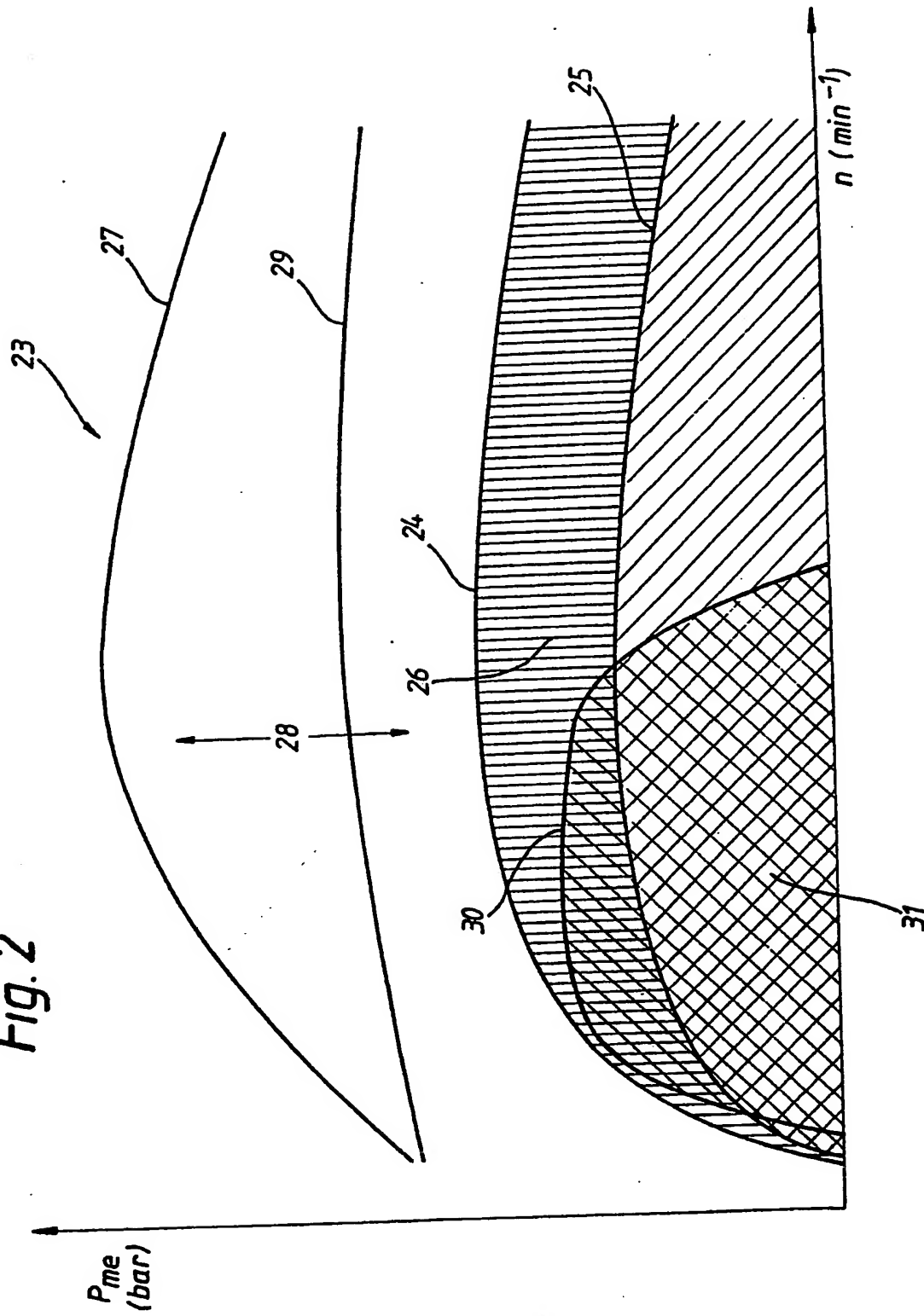
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**Fig. 1**

Fig. 2



A process for regenerating a particle filter located in the exhaust-gas line of a supercharged internal-combustion engine

The invention relates to a process for regenerating a particle filter located in the exhaust-gas line of a supercharged internal-combustion engine, downstream of an exhaust-gas turbocharger, by increasing as a function of operating parameters the temperature of the exhaust gases entering the particle filter, at least part of the main stream of exhaust gas leaving the internal-combustion engine being feedable directly to the particle filter, bypassing the turbine of the exhaust-gas turbocharger.

A process of this type is known from EP-A-260,031. The disadvantage of this process is, however, that, especially in low load and speed ranges, the exhaust-gas temperature necessary for a regeneration of the soot-particle filter cannot be reached because the exhaust-gas temperature, in a diesel internal-combustion engine already low in any case in the operating ranges mentioned is additionally lowered as a result of an expansion of the exhaust gases in the turbine of the exhaust-gas turbocharger.

The present invention is based is, therefore, on providing a process by means of which the particle filter can be regenerated at as many operating points of the internal-combustion engine as possible.

According to the present invention, there is provided a process for regenerating a particle filter, located in the exhaust-gas line of a supercharged internal-combustion engine downstream of an exhaust-gas turbocharger, by increasing as a function of operating parameters the temperature of the exhaust gases entering the particle filter, at least part of the main stream of exhaust gas leaving the internal-combustion engine being feedable directly to the particle filter, bypassing the turbine of the exhaust-gas turbocharger, wherein, in the low to medium load range of the internal-combustion

engine, virtually the entire main stream of exhaust gas is fed directly to the particle filter, bypassing the turbine of the exhaust-gas turbocharger, at the same time the exhaust-gas temperature being maintained at a value necessary for the regeneration of the particle filter as a result of the throttling and/or preheating of the intake-air stream, and wherein, beyond the medium load range up to full load, a part stream of exhaust gas is branched off upstream of the exhaust-gas turbocharger from the main stream of exhaust gas loading the turbine and is fed directly to the particle filter, the part stream of exhaust gas being controlled in such a way that the temperature of the total stream of exhaust gas loading the particle filter reaches the value necessary for regeneration as quickly as possible.

Those exhaust gases guided past the turbine do not undergo any expansion in the turbine of the exhaust-gas turbocharger and therefore also only a slight reduction of temperature. In conjunction with a simultaneous increase of the combustion-process temperature by means of intake-air throttling and/or intake-air preheating, exhaust-gas temperatures sufficient for a self-regeneration of the particle filter are obtained even in the lowest load and speed ranges. In contrast, there is no longer any control of the intake-air stream beyond the medium load range. In order, at the same time, to make it possible always to guarantee a sufficiently high temperature of the stream of exhaust gas entering the particle filter, only the supercharging pressure necessary for the particular current operating point of the internal-combustion engine is regulated, that is to say only some of the exhaust gases are guided via the turbine. The remaining part stream of exhaust gas bypasses the turbine and undergoes no expansion and therefore also no reduction of temperature, so that, in these operating ranges too, the particle filter can be regenerated without difficulty. In the full-load range, the exhaust-gas temperature level is so high that a

regeneration of the filter can take place even without additional measures for increasing the exhaust-gas temperature.

Preferably, in the low to medium load range of the internal-combustion engine up to the medium speed range, an exhaust-gas recirculation additionally takes place. This has the advantage that, in addition, the proportion of nitric oxide in the exhaust gas can be reduced, the recirculation branch-off upstream of the particle filter preventing ceramic particles possibly coming loose from the soot-filter body from being recirculated into the combustion space of the internal-combustion engine.

According to the invention there is also provided a device for carrying out the process according to the invention including: a bypass line branched off from the exhaust-gas line upstream of the turbine of the exhaust-gas turbocharger, the bypass line opens into the exhaust-gas line between the turbine and the particle filter, the cross-section of the bypass line is controllable by means of a first valve arrangement, there is an electronic control unit which, as a function of the internal-combustion engine load and speed, generates a first setting-value signal for actuating the first valve arrangement, wherein, the first setting-value signal is additionally generated as a function of a measured-value signal corresponding to the current value for the supercharging pressure, the cross-section of the charge-air line is controllable by means of the second valve arrangement located downstream of the compressor of the exhaust-gas turbocharger, the first setting-value signal activates the first valve arrangement in such a way that, below a first speed-dependent threshold function for the internal-combustion engine load, the cross-section of the bypass line is at a maximum and above this first threshold function is increasingly reduced with an increasing load according to a family of desired supercharging-pressure characteristics, and the electronic control unit generates, as a function of the

load, speed and supercharging pressure of the internal-combustion engine, a second setting-value signal which activates the second valve arrangement in such a way that, above the first threshold function, the cross-section of the charge-air line is at a maximum and below the first threshold function is reduced.

Two embodiments of the invention will now be described by way of example with reference to the drawing, in which:

Figure 1 shows an embodiment of a device for carrying out the process according to the invention, and

Figure 2 shows the process according to the invention by means of a graph  $p_{me} = f(n)$ .

In Figure 1, 1 denotes a diesel internal-combustion engine supercharged by means of an exhaust-gas turbocharger 2. A soot-particle filter 5 is located in its exhaust-gas line 3 downstream of the turbine 4 of the exhaust-gas turbocharger 2. Upstream of the turbine 4, there branches off from the exhaust-gas line 3 a bypass line 6, the free cross-section of which can be varied by means of a bypass valve 7 located in the branching region. The bypass line 6 opens into the exhaust-gas line 3 again between the turbine 4 and the soot-particle filter 5. Located in the charge-air line 9 extending upstream of the compressor 8 of the exhaust-gas turbocharger 2 is a throttle flap 10, by means of which the free cross-section of the charge-air line 9 can be controlled. The exhaust-gas line 3 and the charge-air line 9 are connected via an exhaust-gas recirculation line 11 which branches off upstream of the turbine 4 and opens into the charge-air line 9 downstream of the throttle flap 10 and the cross-section of which can be controlled via an exhaust-gas recirculation valve 12 provided at the branch-off point. The exhaust-gas recirculation line 11 can alternatively also be branched off between the turbine 4 and the soot-particle filter 5. In both cases, there is the guarantee that particles coming loose from the ceramic body of the soot-particle

filter 5 cannot enter the combustion space of the internal-combustion engine 1.

An air-quantity meter 15 is also inserted, next to the air filter 14, in the intake line 13 extending upstream of the compressor 8. A supercharging-pressure sensor 16 is located in the charge-air line 9 downstream of the throttle flap 10. The two sensors 15 and 16 are connected via measured-value lines 17 and 18 to an electronic control unit 19 which, as a function of these measured-value signals fed to it, generates setting-value signals, of which the first activates the bypass valve 7 via the control line 20, the second activates the throttle flap 10 via the control line 21 and the third activates the exhaust-gas recirculation valve 12 via the control line 22.

The three valves 7, 10 and 12 are activated according to the graph 23  $p_{me} = f(n)$  shown in Figure 2, in which the effective mean pressure  $p_{me}$  plotted on the ordinate is a measure of the internal-combustion engine load and the  $n$  plotted on the abscissa is a measure of the internal-combustion engine speed. Below a first speed-dependent threshold function (24) for the internal-combustion engine load, that is to say in the low to medium load range of the internal-combustion engine, the bypass valve 7 is opened completely. Consequently, virtually the entire main stream of exhaust gas is fed directly to the soot-particle filter 5, bypassing the turbine 4. This prevents the exhaust gases from being cooled excessively as a result of expansion in the turbine 4. In order, even in low load ranges, to obtain an exhaust-gas temperature still sufficiently high for a regeneration of the soot-particle filter, below this first threshold function 24 an adjustment of the throttle flap 10 additionally ensures a reduction of the cross-section of the charge-air line 9, that is to say intake-air throttling with an associated increase in the process temperature. The lower the internal-combustion engine load ( $p_{me}$ ), the more the cross-section of the charge-air



line 9 is reduced. Finally, below a second speed-dependent threshold function 25 of the internal-combustion engine load, located below the first 24, the throttle flap 10 is maintained at its minimum setting. Minimum setting means the throttle-flap position which still allows the internal-combustion engine to run perfectly and which at the same time also guarantees a sufficiently high exhaust-gas temperature for a regeneration of the particle filter 5.

The activation of the throttle flap 10 in the range 26 between the first threshold function 24 and the second threshold function 25 takes place according to a family of desired supercharging-pressure characteristics filed in the electronic control unit 19. In other words, in this range the throttle flap 10 is regulated to an opening position which, at the current speed  $n$  and load  $p_m$  of the internal-combustion engine 1, corresponds to a desired value, determined from this family of characteristics, for the pressure in the charge-air line 9 (supercharging pressure). These desired values are so fixed that the exhaust-gas temperature necessary for the regeneration of the particle filter 5 is reached as quickly as possible.

Above the first threshold function 24, the throttle flap 10 is maintained in the opening position which opens the total cross-section of the charge-air line 9. At the same time, the bypass valve 7 is activated in such a way that, in these operating ranges 28 too (above the first threshold function 24 up to the full-load curve of the supercharged internal-combustion engine 27, the exhaust-gas temperature necessary for a regeneration of the soot-particle filter 5 is reached as quickly as possible. This means, therefore, that, beyond the first threshold function 24, the cross-section of the bypass line 6 is increasingly reduced with an increasing load. In the corresponding rate of the activation of the throttle flap 10 in the range 26, in this range 28, that is to say beyond the medium load range up to the full-load curve

27, the opening position of the bypass valve 7 is determined from a family of desired supercharging-pressure characteristics filed in the electronic control unit 19. The full-load curve for a non-supercharged internal-combustion engine is designated by 29.

To increase the exhaust-gas temperature and, in addition, reduce the nitric oxides present in the exhaust gas, exhaust-gas recirculation additionally takes place in the low to medium load range up to the medium speed range. In the graph 23 of Figure 2, the limiting curve below which exhaust-gas recirculation occurs is denoted by 30. The exhaust-gas recirculation range 31 is located within the "throttling range". So that, despite the frequently changing pressure differences, the exhaust-gas recirculation rate exact for every operating state of the internal-combustion engine within the exhaust-gas recirculation range 30 can be set and regulated accurately, a desired value for the mass intake-air stream is first determined for the particular current operating point (load, speed) from a stored family of desired air-mass characteristics. The value measurable by means of the air-quantity meter 15 (Figure 1) is now regulated to the determined desired value, specifically as a result of the appropriate opening or closing of the exhaust-gas recirculation valve 12. The larger the opened cross-section of the exhaust-gas recirculation line 11, the higher the mass air stream flowing via the intake line 13 or charge-airline 9, and vice versa.

In addition to or instead of intake-air throttling, in a further version of the invention it is also possible, below the first threshold function 24, to employ intake-air preheating in order to increase the process temperature. A possible embodiment of this is represented by dot-and-dash lines in Figure 1.

Upstream of the air filter 14 located in front of the compressor 8, the intake line 13 branches into a first line portion 32 and a second line portion 33. The first line portion 32 carries unheated air. The second

line portion 33 intersects an exhaust-gas heat exchanger 34 located downstream of the soot-particle filter and thus carries preheated air. Located in the branching region is a flap-like mixing valve 35, the position of which determines the mixing temperature of the intake air entering the compressor 8 via the intake line 13. This mixing valve 35 is likewise activatable by the electronic control unit 19 via a control line 36. The mixing valve 35 is controllable continuously between the two end positions 37 and 40. Over the entire load range between full load 23 and no load, as a result of an appropriate activation of the mixing valve 35 the temperature of the intake air entering the compressor 8 is regulated to a desired value which is filed according to a family of characteristics in the electronic control unit 19 and which is a function of a particular operating point. The actual-value measurement is carried out, here, via a temperature sensor 38 which is located in the intake line 13 and which is connected to the electronic control unit 19 via the measured-value line 39. Thus, by an appropriate mixing of the two intake-air streams, there is always the guarantee that, as a result of a controlled increase in the process temperature, the temperature of the total stream of exhaust gas loading the particle filter 5 reaches the value necessary for regeneration as quickly as possible. The additional increase in the process temperature below the first threshold function 24 does not have to take place solely as a result of intake-air throttling or solely as a result of intake-air preheating. In a further embodiment of the invention, it can, of course, also be obtained by a parallel and mutually coordinated use of the two processes.

Claims

1. A process for regenerating a particle filter, located in the exhaust-gas line of a supercharged internal-combustion engine downstream of an exhaust-gas turbocharger, by increasing as a function of operating parameters the temperature of the exhaust gases entering the particle filter, at least part of the main stream of exhaust gas leaving the internal-combustion engine being feedable directly to the particle filter, bypassing the turbine of the exhaust-gas turbocharger, wherein, in the low to medium load range of the internal-combustion engine, virtually the entire main stream of exhaust gas is fed directly to the particle filter, bypassing the turbine of the exhaust-gas turbocharger, at the same time the exhaust-gas temperature being maintained at a value necessary for the regeneration of the particle filter as a result of the throttling and/or preheating of the intake-air stream, and wherein, beyond the medium load range up to full load, a part stream of exhaust gas is branched off upstream of the exhaust-gas turbocharger from the main stream of exhaust gas loading the turbine and is fed directly to the particle filter, the part stream of exhaust gas being controlled in such a way that the temperature of the total stream of exhaust gas loading the particle filter reaches the value necessary for regeneration as quickly as possible.

2. Process according to Claim 1, wherein in the low to medium load range of the internal-combustion engine up to the medium speed range, an exhaust-gas recirculation additionally takes place.

3. A device for carrying out the process according to Claim 1 or 2, including:

- a bypass line branched off from the exhaust-gas

line upstream of the turbine of the exhaust-gas turbocharger,

- the bypass line opens into the exhaust-gas line between the turbine and the particle filter,
- the cross-section of the bypass line is controllable by means of a first valve arrangement,
- there is an electronic control unit which, as a function of the internal-combustion engine load and speed, generates a first setting-value signal for actuating the first valve arrangement, wherein,
- the first setting-value signal is additionally generated as a function of a measured-value signal corresponding to the current value for the supercharging pressure,
- the cross-section of the charge-air line is controllable by means of the second valve arrangement located downstream of the compressor of the exhaust-gas turbocharger,
- the first setting-value signal activates the first valve arrangement in such a way that, below a first speed-dependent threshold function for the internal-combustion engine load, the cross-section of the bypass line is at a maximum and above this first threshold function is increasingly reduced with an increasing load according to a family of desired supercharging-pressure characteristics, and
- the electronic control unit generates, as a function of the load, speed and supercharging pressure of the internal-combustion engine, a second setting-value signal which activates the second valve arrangement in such a way that, above the first threshold function, the cross-section of the charge-air line is at a maximum and below the first threshold function is reduced.

4. A device according to Claim 3, wherein the cross-section of the charge-air line is at a minimum below a second speed-dependent threshold function for the

internal-combustion engine load, located below the first, and in the range between the first threshold function and the second threshold function there is a continuous matching of the charge-air line cross-section, in such a way that the temperature of the total stream of exhaust gas loading the particle filter reaches the value necessary for regeneration as quickly as possible.

5. A device for carrying out the process according to Claim 1 or 2, including,

- a bypass line branched off from the exhaust-gas line upstream of the turbine of the exhaust-gas turbocharger,
- the bypass line opens into the exhaust-gas line between the turbine and the particle filter,
- the cross-section of the bypass line is controllable by means of a first valve arrangement,
- there is an electronic control unit which, as a function of the internal-combustion engine load and speed, generates a first setting-value signal for actuating the first valve arrangement, wherein
- upstream of the compressor of the exhaust-gas turbocharger, the intake line is branched into a first line part carrying unheated air and into a second line part carrying preheated air,
- a mixing-valve arrangement is located in the branching region,
- the first setting-value signal activates the first valve arrangement in such a way that, below a first speed-dependent threshold function for the internal-combustion engine load, the cross-section of the bypass line is at a maximum and above this first threshold function is increasingly reduced with an increasing load according to a family of desired supercharging-pressure characteristics, and
- the electronic control unit generates, as a function of the load, speed and intake-air temperature, a second setting-value signal which activates

the mixing-valve arrangement in such a way that, over the entire load range of the internal-combustion engine, the temperature of the intake air entering the compressor corresponds to a desired value which is filed according to a family of characteristics in the electronic control unit and which is a function of a particular operating point, the desired value being determined so that the temperature of the total stream of exhaust gas loading the particle filter reaches the value necessary for regeneration as quickly as possible.

6. A device according to Claim 5, wherein the second line part is guided via an exhaust-gas heat exchanger.

7. A device according to any one of Claims 3 to 6, wherein,

- an exhaust-gas recirculation line branches off from the exhaust-gas line upstream of the turbine and opens into the charge-air line upstream of the compressor,
- an exhaust-gas recirculation valve is located along the path of the exhaust-gas recirculation line, and
- the electronic control unit generates, as a function of a measured-value signal fed to it and corresponding to the mass intake-air stream, a further setting-value signal which activates the exhaust-gas recirculation valve in such a way that the latter is in an opening position below the first threshold function and up to the medium speed range of the internal-combustion engine.

8. A device according to Claim 7, wherein, the degree of opening of the exhaust-gas recirculation valve is determinable from a family of desired intake-air mass characteristics filed digital-electronically in a read-only memory of the electronic control unit.

9. A process for regenerating a particle filter, located in the exhaust-gas line of a supercharged internal-combustion engine downstream of an exhaust-gas turbocharger, substantially as described herein with reference to, and as illustrated in, the accompanying drawings.

10. A device for carrying out the process of claim 9, substantially as described herein with reference to, and as illustrated in, the accompanying drawings.



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